HamSCI as a Tool for Equatorial Plasma Bubbles Study

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Abstract

Equatorial Plasma Bubbles (EPBs) are **nighttime** and **low-latitude** ionospheric disturbances that degrade passing through radio wave signals, resulting in unstable radio wave reception. With an **upwelling at the bottom-side** ionosphere and a **sudden depletion in electron density** accompanied by **irregularities at various scales**, EPBs directly affect HF skywave propagation across a broad range of frequencies, where the bottom-side ionosphere plays a crucial role in HF reflection and refraction. The HamSCI spots database, derived from the Reverse Beacon Network (RBN), Phase Shift Keying Reporter (PSKReporter), and Weak Signal Propagation Reporter Network (WSPRNet), provides information on successful HF radio wave links from the amateur radio community. This work reports efforts to retrieve EPB characteristics from HamSCI spot data.

Introduction

Equatorial Plasma Bubbles

Produce of 3 phases of electrodynamic process

- Amplification of **upwelling** amplitude during F-layer **PSSR***
- Launching of the **first bubble** from the **upwelling crest**
- **Structuring** of plasma within the upwelling

*PSSR: Post Sunset Rise

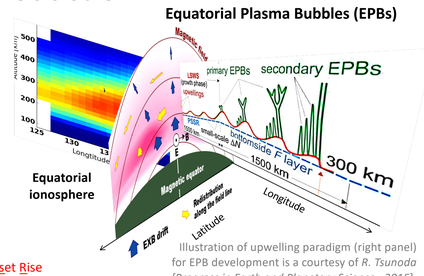


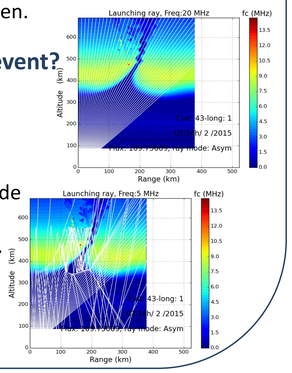
Illustration of upwelling paradigm (right panel) for EPB development is a courtesy of *R. Tsunoda [Progress in Earth and Planetary Science , 2015]*.

ISS-detected altitudinal structure of EPB

- The images were taken onboard the ISS by an astronaut using a Nikon D3s.
- Each image was **multiplied by its red channel ~15 times** to enhance the structures of the red emission associated with **atomic oxygen in the F layer**.
- Upwellings and plasma depletions are clearly seen.

How does HF wave propagate during EPB event?

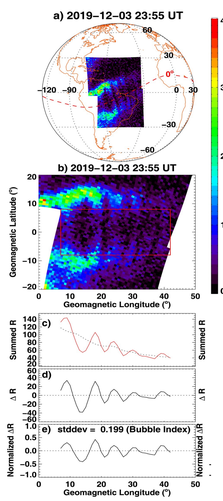
- EPBs were simulated by 3-D high-resolution bubble (HIRB) model [*Yokoyama et al., 2015*].
- Altitudinal tilt structure due to velocity shear
- Depending on the scale size and structures inside the EPB, **different frequencies** in the HF band have **different propagation responses/ effects**.



Unpublished result regarding NICT-CNES collaboration >>
[*Courtesy of S. Rougerie*]

Data and Methodology

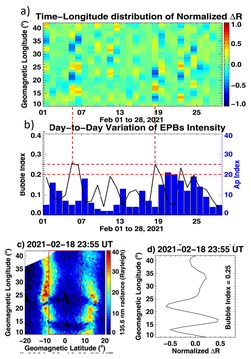
Bubble index over the American/Atlantic sector using GOLD nighttime disk image data [*Ar et al., 2023*]



<< GOLD nighttime partial disk image map of OI 135.6 nm radiance at 23:55 UT on 03 December 2019 in (a) geographic and (b) geomagnetic coordinates. The box marks the selected equatorial area between ±8° MLAT. (c) Longitudinal variation of the MLAT-integrated radiance (red curve) and its running average reference (black dotted line). (d and e) Longitudinal variation of the differential radiance (ΔR) and normalized ΔR, respectively. ***The standard deviation of the normalized ΔR was calculated as the Bubble Index.***

(a) 2-D Temporal-longitudinal distribution of the normalized ΔR and (b) 1-D temporal variation of the corresponding Bubble Index and Ap index during February 2021. >>

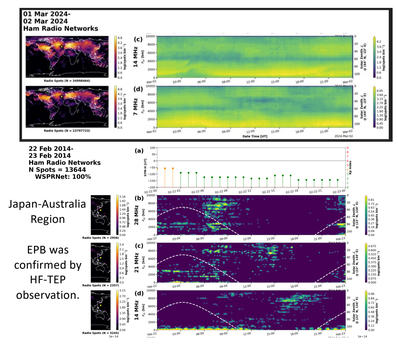
(c) GOLD nighttime image of OI 135.6 nm radiance in geomagnetic coordinates and (d) the longitudinal variation of the normalized ΔR at 23:55 UT on 18 February 2021. >>



"strong EPBs corresponding to 0.2 and above, modest EPBs between 0.1 and 0.2, faint or no EPBs if below 0.1"

Days with bubble index ≥ 2.5 : 5, 18 February 2021

Amateur Radio: HamSCI Spot Data



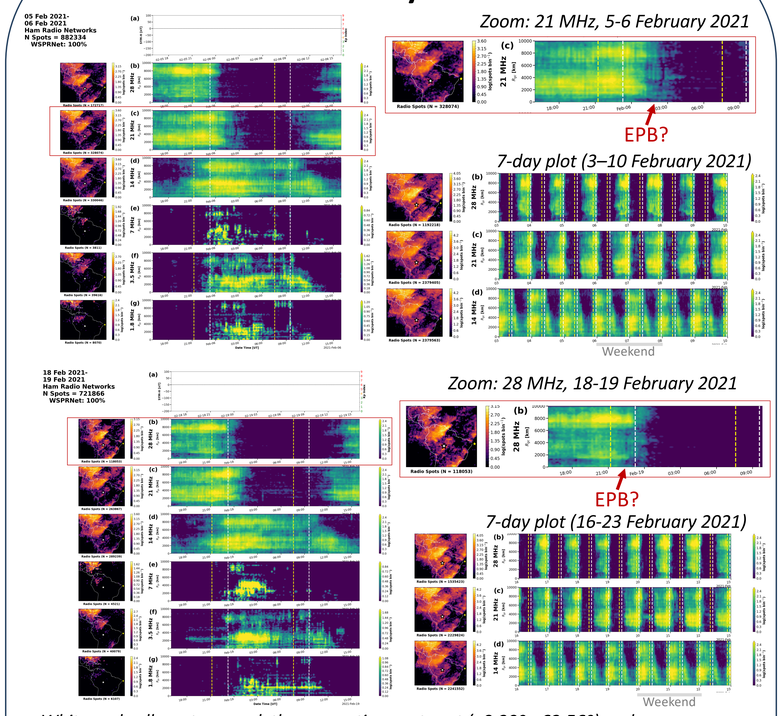
- Significant coverage of HamSCI data density plot during a single day allows us to try using it as observational platform for EPBs study.
- Previously, we focused on the Japan–Australia region, but we found that the available spots for the years of interest (2013–2015) were not dense enough in that area.
- Therefore, **we have shifted our study region to the Americas.**

Region: American sector (30ºW – 100ºW, 30ºN – 30ºS).

Calculate sunrise/sunset times at F-region (300 km alt).

Plot spot density and propagation range.

Preliminary Results



White and yellow stars mark the magnetic equator at (−9.29º,−62.56º) and (−7.21º,−32.32º), respectively. White (or yellow) dashed lines indicate sunset and sunrise at the corresponding white (or yellow) location, at an altitude of 300 km.

Summary

- We focus on 5 and 18 February 2021, when the bubble index ≥ 2.5.
- A sudden depletion in the spot count is observed between the 3000–7000 km propagation range during 02:00–03:00 UT on 5–6 February 2021.
- Similarly, a depletion in the spot count is observed between the 2000–6000 km propagation range during 22:00–23:00 UT on 18–19 February 2021.
- These observed depletions may suggest an EPB signature in the HamSCI spot data.

References

- Tsunoda, R.T. (2015), Upwelling: a unit of disturbance in equatorial spread F, Prog. in Earth and Planet. Sci. 2, 9, https://doi.org/10.1186/s40645-015-0038-5.
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Acknowledgements

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